Precision Scintillators

*Model 111B "Scintillator"**
and
*Model 117 "Special Scintillator"**

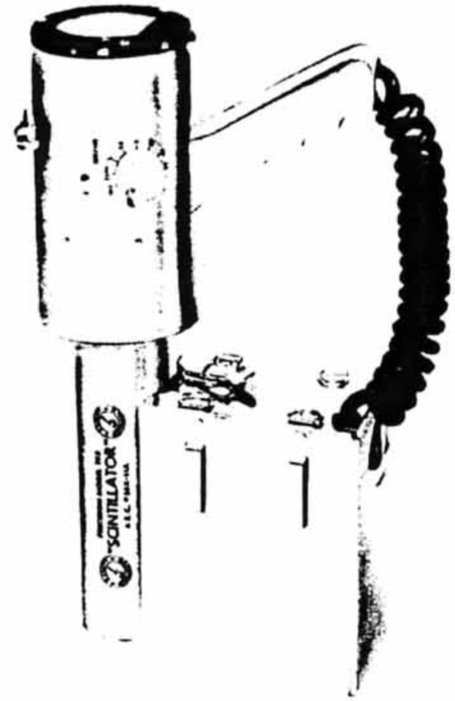
*Reg. U.S. Pat. Off.

Operation and Maintenance Manual

QUALITY INSTRUMENTS

PRECISION RADIATION INSTRUMENTS, INC.
2235 S. La Brea Ave. • Los Angeles 16, Calif.

World's Largest Manufacturer of Portable Radiation Instruments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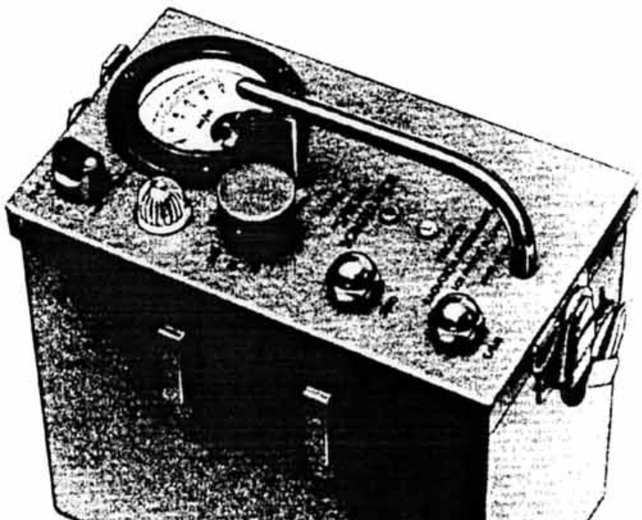

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Precision Radiation Instruments, Inc.

INSTRUCTION AND MAINTENANCE MANUAL

for

MODEL 111B "SCINTILLATOR"*

MODEL 117 "SPECIAL SCINTILLATOR"*

I. Advantages of Scintillation Counting

The presence of gamma radiation can be determined by taking a reading with a Geiger Counter or a Scintillation Counter. The two types of instruments are used in a similar manner. The major difference between them lies in the detecting element. The Geiger Counter uses a Geiger-Mueller tube which is filled with a gas, whereas the Scintillation Counter uses a Sodium Iodide crystal, which is very dense, as its detecting element. The crystal, if sufficiently thick, intercepts practically every gamma ray that strikes it, whereas the Geiger tube reacts to less than 1% of the gamma rays that penetrate it. As a result, the Scintillation Counter records many times the number of rays that the Geiger Counter can from the same source. This makes the "Scintillator" a more sensitive instrument than a Geiger Counter. Another important result is that a steadier meter reading for a given field of radiation is obtained, because the "Scintillator" is averaging many times the number of counts per time interval as the Geiger Counter. This effect is particularly important when measuring small amounts of radiation. As a result, a small difference in intensity can be read easily on the Scintillator" when the same difference would not be recognizable on the Geiger Counter, due to its erratic meter movement. This is the factor that makes the "Scintillator" so valuable for uses such as prospecting where a small indication is sometimes very important.

II. General Description

The Model 11IB consists of two separate parts, which are connected by a cable. One portion of the instrument contains most of the electronic components and the detecting element. This portion is the "probe." The other part of the instrument is the battery box which contains the batteries. The probe attaches to the battery box with a snap catch. The probe can be separated from the battery box by releasing the snap fastener on the top of the battery box and pulling the probe away from the battery box. For survey work, the probe docs not have to be removed from the battery box.

The probe may be removed from the battery box and placed in any position which will offer greater sensitivity. Since the detecting element, the sodium iodide crystal, is mounted in the bottom of the narrow end of the probe (opposite the meter end) there should be as little obstruction as possible between this portion of the probe and the area being surveyed. The end of the probe need not be pointed directly at the radioactive source to get a reliable response.

In the Model 117, all the parts are mounted inside the case. The crystal is located just behind the spot on the end of the case marked "Sample Check Spot." This is the most sensitive point on the instrument. The neon bulb on the top panel of the 117 is a pilot light and does not flash to indicate the presence of radioactivity.

III. Definition of Terms

There are terms encountered in the use of radioactive materials which are peculiar to this field and which should be explained in order to make this text more understandable.

Radioactivity: The process whereby certain elements emit particles or rays due to the disintegration of the nuclei of their atoms. The main types of radioactivity are alpha particles, beta particles and gamma rays. Gamma rays penetrate matter in much the same manner as X-rays. Since gamma rays are the only type of radiation with penetrating power, they are the only ones that are important to the prospector. Scintillation counters have great sensitivity to gamma rays. They do not respond to alpha or beta particles.

Milliroentgen: the common unit of radiation. This term is usually expressed with a unit of time; i.e., milliroentgens per hour (abbreviated MR/HR), and expresses the number of units of radiation intensity in a field. If a man stays twelve hours in a radiation field whose intensity is five milliroentgens per hour, he will have been exposed to 60 milliroentgens. This is the maximum amount which the Atomic Energy Commission considers to be entirely harmless even when repeated day after day.

Background: a certain portion of any radioactivity measurement is not attributable to the radioactive sample being measured, but comes from other sources. This portion of the measurement is called "background." It is caused by cosmic radiation, natural radioactivity of the earth, and other sources. Since background can vary greatly, it must be measured separately and subtracted from any measurement upon which it will have an effect.

EXAMPLE:

Sample reading	**.35MR HR**
Background reading	**<u>.02 MR/HR</u>**
Corrected reading	**.33 MR/HR**

In order to correctly establish the background effective in the measurement of a particular sample, the sample must be moved far enough away from the instrument so that is has no effect on the background reading.

IV. Description of Controls

A. MR/HR Range Control.

The range control has eight positions. The use of each of these positions is as follows:

1. **"OFF"; when the knob is turned to this position, the entire instrument is turned off.**
2. **"ZERO"; when in this position, the instrument can be electronically zeroed.**
3. **"5"; when in this position, the instrument is set at the highest range. A full scale indication on the meter means the instrument is exposed to a radiation intensity of 5 milliroentgens per hour.**
4. **All succeeding positions on the range control, 5 2.5, .5, .25, .05, .025, mean that when the range control is set to one of these values, a full scale reading indicates an intensity in MR/HR equal to the value selected on the control. Note: The "5" range measures the largest amount of radioactivity and is the least sensitive range. The ".025" range is the most sensitive range.**

B. "TIME CONSTANT" Control.

Model 111B: The use of the time constant control is as follows: One of three positions can be selected by turning the knurled knob to "FAST," "MEDIUM" or "SLOW." The function of the "MEDIUM" and "SLOW" controls is to make the meter response slower than when the control is set to "FAST." If the "FAST" time constant is in use, the meter will respond very rapidly to any change in radiation intensity. Since the gamma rays do not occur at evenly spaced intervals, the "FAST" time constant allows the meter indication to fluctuate, especially if the intensity is very low. The "MEDIUM" and "SLOW" time constants slow down the meter reaction to changes in intensity, thus giving *a more* stable, easier-to-read indication. The "FAST" time constant may be used for prospecting if the *average* value of the fluctuating reading is taken. It should be used for deciding on what range to set the range switch and for checking approximate levels of radiation. It is also desirable to use the "FAST" position when traveling at high speeds. The "MEDIUM" and "SLOW" positions should be used for obtaining more accurate readings. When using the "MEDIUM" position, the meter should be observed for at least 15 seconds, and the average reading used. In the "SLOW" position, it will take about one minute for the meter to reach its final reading.

Model 117: The principles of operation are the same as outlined above, but Model 117 has only two time constants, "FAST" and "SLOW."

C. "ZERO" Control.

The "ZERO" Control is one of the two controls which are covered by cap nuts. The instrument can be electronically zeroed with this control by first turning the "ON-OFF" range control to the "ZERO" position. The meter will momentarily give a reading and then return to zero. If the meter does not return to zero, remove the cap from the control and adjust this control until the meter does indicate zero. Since the meter zero position will change as the battery voltages change, it is necessary to check the zero position periodically during use. Such checks should be made in the first few minutes of operation and every half hour or hour thereafter as experience proves necessary. There is no set rule for the frequency of such checks because the rate of change of the zero position will depend upon the age of the batteries, the temperature and minor variations in the vacuum tubes used in the instrument.

D. "CALIBRATION ADJUST" Control.

This control labeled "CALIB. ADJ." on the Model 11IB and "CALIB." on Model 117 is covered by a cap nut. It is used to compensate for changes in the battery voltage as the batteries wear out. A calibrated check source — a trace of radium scaled in a plastic disk — is provided so that the user can conveniently check the instrument for such changes. Turn the switch to the .25 MR/HR scale and hold the check source flat and well centered against the end of the Model 11IB probe or against the "Sample Check Spot" of the Model 117. After noting the reading, turn the disk over and repeat the measurement to discover which side gives the higher reading. Finally, with that side which gives the higher reading turned against the instrument, note whether the meter reading in MR/HR agrees with the number stamped in red on the disk. If necessary remove the cap nut, and with a screw driver, turn the calibration control until the meter gives the reading which is stamped on the check source. The highest accuracy will be achieved in this operation if the instrument is switched to "slow" response time. For the best results the setting of the calibration control should be checked each time the zero control is checked. Never adjust the calibration control unless the zero control has been checked first.

V. Meter Readings

The meter, in order to accommodate a greater number of ranges, has been provided with two separate scales. Each scale is read from left to right, is divided by five major divisions and fifty minor divisions.

The first scale, at the top of the meter face, reads from 0 to .25. When a range is selected with the range control, the user reads from the meter scale which corresponds to this range. The 0 to .25 scale can be read with three separate ranges, as selected with the range control. These ranges are "2.5 MR/HR," ".25 MR/HR" and ".025 MR/HR." When using the 2.5 MR/HR range, each major division is equal to 1/5 of the full scale reading, or .5 MR/HR; the first major division reading being .5 MR/HR; the second 1 MR/HR, and so on. When using the .25 MR/HR range, the only difference in readings taken is the placement of the decimal point. The first major division reading would be .05 MR/HR; the second, .1 MR/HR; and so on up to .25 MR/HR. The same rule applies when the .025 range is used; the only difference being in the placement of the decimal point. The first major division would then be equal to .005 MR/HR; the second, .01 MR/HR and so on, up to .025 MR/HR.

EXAMPLE:

Range control set at "2.5"
Meter needle deflected to read ".15" on the top scale.
MR/HR intensity: 1.5 MR/HR.
Range control set at ".25"
Meter needle deflected to read ".15" on the top scale.
MR/HR intensity: .15 MR/HR. Range control set at ".025" Meter needle deflected to read ".15" on the top scale. MR/HR intensity: .015 MR/HR.

The second scale is printed on the meter face just below the first scale and reads from 0 to 5. Here, each major division is equal to 1/5 the full scale reading as in the previous scale. The ranges, as selected with the range control, which can be read from this scale are "5," and ".5" and ".05." When the range control is in the "5" position, all readings on this scale can be taken directly with each major division representing 1 MR/HR. The first major division (marked "1") equals 1 MR/HR; the second, 2 MR/HR; and so on, up to 5 MR/HR. When the range control is in the ".05" position, the scale should read as follows: the first major division (marked "1") is equal to .01 MR/HR; the second, .02 MR/HR; and so on, up to .05 MR/HR.

EXAMPLE:

Range control set at ".5"
Meter needle deflected to read "3" on the scale.
MR/HR intensity: .3 MR/HR.

Note that changing the range switch setting cannot change the amount of radiation to which the instrument is exposed and so cannot change the reading to be taken. The range switch does affect the amount by which the meter deflects and so determines which set of numbers are to be read on the meter scale. In general the setting of the range control should be chosen so that the meter gives the largest possible deflection without going off scale to the right.

EXAMPLE:

Range control set at ".5"
Meter needle deflected to read—"2" on lower scale. MR/HR intensity - .2 MR/HR.

It would be better to make this last reading on the next more sensitive range:

Range control set at ".25"
Meter needle deflected to read—".2" on upper scale. MR/HR intensity - .2 MR/HR.

The instrument is calibrated in MR/HR rather than counts per minute because this is a more meaningful and reliable method of measurement. The reading in counts per minute in a given field of radiation may vary widely, whereas the intensity in MR/HR is a constant value.

VI. Operating Instructions

A. Turn the "ON-OFF" range control to "zero." There will be a momentary meter reading and the needle will then return to zero. If it does not return to zero, remove the cap from the ZERO control and adjust until it does indicate zero.

B. Turn the "ON-OFF" range control to the "5" MR/HR range and bring the probe to the point from which you wish to measure the sample. If the meter reading is below 2.5 MR/HR, turn the control to the next lower position (2.5). If the meter reading is below .5 MR/HR, turn the control to the next lower scale (.5) and so on. When measurements are taken, the user should always turn the range control to the lowest possible range upon which he can obtain a reading, preferably the .025 range. The range should be increased only if the needle goes off scale to the right on the range being used. If the 5 MR/HR, or highest range, is used and the meter is still off scale to the right, the probe end may be moved back away from the activity until a reading can be made. If the probe does have to be moved back from the sample to acquire a reading, and the intensity of the sample is to be compared with the intensity of another sample, caution should be taken to make sure that the distance from the samples is the same for both readings. The "INVERSE SQUARE" law applies here. That is, the intensity of the radiation decreases in proportion to the square of the increase in the distance from the sample. The distance should be measured from the center of the sample to the center of the crystal inside the probe.

EXAMPLE:

Reading from sample at 3 inch distance — 2 MR/HR.
Reading from sample at 6 inch distance — .5 MR/HR.

By taking a reading from this sample at 6 inches, the distance from which the first reading was taken has been doubled, i.e., the distance has been multiplied by 2. Since the radiation intensity decreases in proportion to the square of the increase in the distance, the reading at 6 inches must be 1/4 of the reading at 3 inches, i.e., the factor of increase in distance is 2; 2 squared is 4, therefore the first reading (2 MR/HR) is divided by 4 when the distance from the sample is doubled. 2 MR/HR divided by 4 equals .5 MR/HR.

From this example, it is apparent that if readings are taken from two samples to determine the relationship between the amount of radioactivity in each, any difference in the distance at which these readings are taken can cause a large error if the inverse square law is not taken into consideration. When the sample is very large, as for example a bin of ore, the inverse square law is not effective at close range but the radiation near a large pile of ore tends to be constant.

C. Changing time constant settings may be desirable during a measurement to reduce meter needle fluctuation. The time constant control can be used to obtain quick readings on the "FAST" position or may be changed to the "SLOW" position if the needle fluctuation is too great to allow an accurate reading. It is important for the user to remember that when the slow time constant is used, the meter takes longer to reach its final reading (about 1 minute) and he should wait until the needle has reached the end of its travel. To make the most accurate readings the user should watch the meter for about one minute after it has reached its apparent final value. The most accurate reading can then be taken as the average of all the readings indicated by the meter needle in that time. Somewhat better averages can be made by waiting three or four minutes. With practice it is possible by this method to obtain successive readings which agree within 2 or 3 of the smallest meter divisions on the most sensitive range.

D. Occasionally, it is desirable to check the calibration of the instrument. The procedure for checking calibration on the Model 11IB is outlined in Section 1V-D. This procedure should be repeated after the instrument has had an hour or more of continuous use and after a rest period of an hour or more. After the instrument has been in use for some time, the calibration control will no longer bring the meter to the desired reading. This usually indicates the batteries are exhausted and should be

replaced.

VII. Use of Recorder with 111B

The Model 111B may be used with a continuous strip recorder. However, the electrical output of the Model 111B is not sufficient to operate a recorder. In order to increase the output to the level at which a recorder will work, it is necessary to use a preamplifier. The MODEL 116 PREAMPLIFIER made by P. R. I. (price $99.50) is especially designed for this purpose. There are two tip jacks located on the 111B probe marked "recorder," to which the preamplifier may be connected. A suitable recorder is the AW portable, 1 MA. D.C. type #2 minute feed spring-drive recorder. This recorder is manufactured and shipped by the Esterline Angus Co., but may be ordered from Precision Radiation Instruments, Inc., at a price of $335.00.

VIII. Prospecting for Uranium

A very important factor in seeking radioactive minerals is to know when the instrument being used is actually giving an indication of the presence of such minerals. The Scintillators have been used in mines of known value to determine what happens when a deposit of radioactive material has been encountered. The radioactivity inside a good uranium mine may be 10 to 100 times greater than that over normal ground.

The normal background reading will usually fall between .005 and .03 MR/HR, depending on location and other factors. Some prospectors adhere to the policy that any reading over normal background is good excuse for further investigation of the location; such as surveying the surrounding area or taking samples from below the surface. This is good practice since a deposit may be buried under rock or soil overburden which would reduce the intensity reading at the surface or in the air above it. An indication of as little as 10% above background may indicate the presence of a valuable uranium deposit. There are several ways in which to search for uranium with a scintillation meter. The method used should be chosen to fit the prospector's particular requirements.

The most direct method is to simply hold the scintillator close to a sample of every type of rock encountered on a prospecting mission. If any sample shows higher than normal radioactivity then its origin should be located and more samples tested until it can be determined whether or not significant values of radioactivity are present. The scintillation counter, however, is so sensitive that it is not necessary to hold it close to each sample of rock. Many prospectors, therefore, prefer to carry the instrument in a car or truck and to stop for more detailed investigation whenever an area of slightly higher than average radioactivity is encountered.

If the survey is conducted from a moving vehicle, the location where an increase in meter reading is encountered should be noted. If possible, a survey should be made from the vehicle, or on foot, in a circle of 50 yards radius around the location. If nothing further is encountered, this would indicate that the material is in a pocket, or that the rest of the vein is covered by a large quantity of earth or rock. At this point, the prospector may dig below the surface to determine the size and value of his original find, or look further for a larger indication in another location. Care should be taken in planning surveys to make sure that as much of the area as possible is surveyed.

Samples should be collected from the area of high radioactivity and should be checked by holding them against the sensitive end of the probe (or the Sample Check Spot on the Model 117), and observing the meter reading. If the ore appears to have promise, send at least a one-pound sample to the U.S. Geological Survey, Geochemistry and Petrology Branch, Bldg. 213, Naval Gun Factory, Washington, D.C. They will assay the sample without charge and give their report only to the individual submitting the sample. If their report indicates the ore has commercial value, it should be offered to the US. Atomic Energy Commission, 70 Columbus Avenue, New York 23, New York, Attention: Raw Materials Operations.

The best method for locating radioactive deposits is to construct radioactivity contour maps or grids. To do this it is necessary to systematically take readings over a large area and to record them on a map. The area to be explored should be ruled off like a checkerboard or grid and readings should be made at the corners of every square. In preliminary work, when it is desirable to cover the most ground in the shortest time, the squares may be made quite large, say 300 feet on a side. If after all the readings have been mapped, there appear to be significant variations in some part of the area covered, then, in the region of interest, additional readings should be made at the centers of each of the squares. This will generally produce a total set of readings from which reliable radioactivity contours (called *isorads)* may be drawn. The purpose in making the additional set of readings at the center of the squares formed by the first set is to obtain the most uniform coverage, i.e., each new point is located at the maximum possible distance from all other points.

When taking readings in this manner it is desirable to hold the instrument as high above ground as convenient so that the radioactivity from a fairly large area of ground is averaged in the measurement at each point. The choice of distance to be used between points in such a survey depends very much upon the local topography. For example, if the region is very flat with few or no outcroppings, then fairly large distances between points may be used. If, however, the terrain is very irregular, the readings should be taken at intervals close enough together to insure that at least a few readings are taken near each topographic feature. For purposes of finally determining the extent of a newly discovered radioactive ore body, readings are often taken every 10 to 20 feet.

After a satisfactory number of readings have been taken in an area and recorded in their respective locations on a map, it will be found generally that the easiest way to develop contours is to divide all the readings into three ranges, high, intermediate, and low; then with a red pencil circle each high value and, with a blue or green pencil, circle each low value. By holding the map at some distance from the eyes, it usually will be possible to distinguish any significant pattern that may be present.

If there are any well defined areas in which the readings are uniformly high, or in which only one figure is outstandingly high, then such areas should be investigated further by taking readings on particular samples or by making radioactivity measurements in test drill holes put down to whatever depth is practical for the area. To measure radioactivity in drill holes the Precision Radiation Instruments Model 120 Drill Hole Geiger Counter is recommended.

For additional information on prospecting, the book "PROSPECTING FOR URANIUM," can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D.C., price 55 cents.

IX. Airborne Uranium Surveys

Aerial surveys require more careful planning because of the greater speed at which an aircraft travels. It is customary to mark a rectangular area on a map, then fly over the area from one end to the other as one would plow a field. The aircraft should fly at the slowest speed and lowest altitude consistent with safe-flying. Atomic Energy Commission aerial surveys with the Model 111 are made at altitudes of 50 to 100 feet above the ground. Surveys by the United States Geological Survey with the 111 are flown at 500 feet. The recommended flying speed is 80 to 100 m.p.h. Sometimes easily located objects such as long streamers are dropped on locations where high readings are noted and these locations are later surveyed from the ground.

In some aircraft the self-luminous meter faces on the control panel contain enough radium to interfere with the measurement of the low values of radioactivity found in survey work. Such "stray" sources of radioactivity cause interference in two ways. First, they can cause an increase in the normal amount of fluctuation in the radioactivity reading and so prevent accurate measurement of very low radioactivity values. Second, a more serious kind of error can occur due to variations in the amount of such stray radioactivity reaching the scintillation meter as a result of the change of position of the pilot or passengers during flight. Since the human body absorbs more than half of the radium rays striking it, fictitious changes in survey reading can be caused by a person entering or leaving the cockpit.

Whether or not such interference exists in the scintillator readings can be determined simply by taking two readings of background radioactivity in an area remote from other aircraft. The first reading should be taken inside the plane with the probe in the position it would normally occupy during flight. A mark should BE made on the ground indicating the position over which the probe was positioned during the first reading. Note also the height above the ground of the probe during the first reading. Move the plane and replace the instrument in — as nearly as possible — the same position it occupied for the first reading. Take the second reading, and the difference between the two is assumed to be the amount of radioactivity from the control panel. If the aircraft control panel contributes more than .002 MR/HR to the scintillator readings, one or more of the following steps should be taken to reduce the effect.

(a) The instrument may be mounted farther back in the plane. (Doubling the distance from the control panel) will reduce its effect four-fold.)

(b) The meter faces may be changed to employ ultraviolet or other illumination instead of radium self-luminous paint.

©) Mount the scintillator in a lead shield so that only those radioactive rays coming from below the plane can reach the scintillation crystal. Such a shield should be an inch thick to insure protection from any excessive amount of stray radioactivity; however, if the amount of stray radioactivity is not large, a !/4" thick shield may suffice. (One-half inch of lead will absorb about 70% of the radioactive rays striking it.)

X. Detection Range

It is not possible to specify the distance at which a "Scintillator" will detect a deposit. This depends on many factors such as the size and quality of the deposit, the thickness and type of overburden covering the deposit, whether the overburden itself is radioactive, etc. It appears that important though very small traces of radioactivity are often located in the soil many yards away from, or over the actual ore body. Such traces of radioactivity produce a weak response in the scintillation counter as though the rays from the actual ore body were penetrating the intervening amount of soil or overburden. In one case, by careful measurements and the use of contour maps, a large body of uranium ore was discovered 200 feet below the surface. The radioactivity at the surface of the earth over the ore was only twice that of the surrounding area. Upon drilling a test hole down to the ore, it was found that the telltale radioactivity was located entirely in the top five or six feet of earth. At a distance of 100 feet below the surface (and 100 feet from the ore body) there was actually less radioactivity than occurred on the surface.

Experiences of this kind are common enough to say that there is no simple answer to the question, "How deep may buried ore be detected." It can be shown that a very few feet of barren quartz or limestone can almost completely absorb the rays from a large body of uranium beneath it. But it is also true that telltale traces of uranium are often found at large distances from the parent body and these traces often enable the prospector to locate the real vein.

XI. Assaying with a Scintillation Counter

There are in general, two ways in which to determine the amount of uranium in ore. The most fundamental way is to directly measure the uranium in a sample by chemical means. Chemical assays are essentially infallible, but they require the use of a chemical laboratory and are relatively time consuming.

The other method of assaying uranium ore is the so-called radiometric method. This method is based on the fact that almost always, the amount of radioactivity of a sample of ore (which can be measured with a Scintillator) is proportional to the amount of uranium in it. There are some important exceptions to this, however. Uranium is not the only radioactive clement which occurs in nature. Thorium is a radioactive metal, somewhat similar to uranium and in some regions the two metals occur in the same minerals. For example, in Southern California several deposits are known to contain both thorium and uranium. The radioactivity of such ores cannot be used as an accurate measure of the uranium content since the radioactivity due to thorium cannot be easily distinguished from that due to uranium. The accuracy of a radioactive assay is also sometimes influenced by the fact that the radioactivity of uranium itself — alpha particle emission — is not the kind which can be detected on scintillation counters. However, the products of the radioactive decay of uranium are themselves radioactive and two of these, radium and radon, are actually responsible for most of the radioactivity observed in uranium ores. Because radium is chemically much different from uranium, when uranium ore is exposed to the weathering action of air and water, at the surface of the earth, the radium may be dissolved away and redeposited nearby in other rocks. Thus, samples of weathered uranium ore may exhibit higher or lower amounts of radioactivity than would be expected on the basis of their true uranium content.

In spite of these potential hazards, the method of radiometric assaying is so convenient that it is very frequently used and a high degree of accuracy can usually be obtained. For example, in most mines the ratio of radioactivity to uranium content is quite constant for ore mined below the surface weathered zone. Once the ore has been properly sampled and assayed by chemical means and its radioactivity measured, then the probable assay of other ore from that same mine can be taken in proportion to its radioactivity. Also, for areas known to be "in equilibrium" and free of thorium, it is possible to predict quite accurately the amount of radioactivity associated with uranium by radiometric assaying. The following methods of radiometric assaying with a 111B have been developed to apply to various field situations. Method "A" can be used with the Model 117, but a 111D is required for Methods "B" and "C."'

Method "A" (Hand Specimens). For very rough estimates of assay value which can be made "on the spot," in the field, select a nearly round piece of ore weighing about 1/4 of a pound and hold it right against the scintillator's sensitive area. Such a specimen will produce a reading in MR/HR which is approximately one-tenth the percentage of uranium (U_3O_8) it contains. That is, a sample containing 1% U_3O_8 will give a reading of about .1 MR/HR over the normal background reading. If the specimen is not of uni form composition, several readings should be taken on different sides and the best estimate will be the average of the readings.

Method "B" (Large samples for appraisal of new finds). For assays accurate to about 85% a fairly large (several pounds) sample of ore should be taken from the vein deposit or outcrop. Such a sample should be taken so that as far as possible it represents a true cross-section of the ore that might be actually mined and sold. The whole sample should

be pulverized and well mixed.

To determine the percent of uranium contained in the sample, first set the time constant switch on the 111B to slow, check the zero adjustment and calibration control setting, then:

1. Place the end of the 111B probe flat against the top of the cover of the assay container supplied with the 111B.
2. Take the background reading.
3. Fill container to the point indicated with pulverized ore and take a second reading with the probe in the same position as in the first step.
4. Deduct the background reading from the ore reading.
5. Multiply the answer by ten for percentage of uranium.

EXAMPLE:

Background reading	.01 MR/HR
Ore reading	<u>.03 MR/HR</u>
Difference	.02 x 10 = .2

The ore is approximately two-tenths of 1% uranium.

Method "C" (Ore Control in Developed Mines). The preceding methods of assaying ore are based upon the assumption that the ore contains no thorium, that the uranium is present with a precisely known percentage trace of radium, and that the instrument has been perfectly calibrated. The following procedure specially suited to use of the 111B tends to make these assumptions unnecessary. It is especially useful for monitoring quality of ore being shipped from a mine. With this procedure assays of better than 95% accuracy can be obtained. In brief, the method is to calibrate the scintillator with a known quantity of ore which has been chemically assayed, replace the known ore with the sample to be measured.

The reading due to the new sample will be directly proportional to its uranium content, provided only that it is the same type of ore as that which had been assayed.

Put an exactly weighed sample (about 1 ½ pounds) of assayed pulverized ore in a ring shaped container, like a jello mold tin, the inner diameter of which is about 2 ½" in diameter and the outer diameter of which is about 4 ½" (container should be at least 3" high).

After checking the zero of the 111B Scintillator, insert the probe into the center of the ring so that the crystal in the probe end is surrounded by the ring of powdered ore. Adjust the calibration control of the instrument so that the instrument reads in MR/HR the same value as the percent of U_3O_8 in the ore sample. Without touching the calibration control, replace the assayed sample with an exactly equal weight of the pulverized ore to be assayed. Record the new reading of the scintillator. Remove the second sample of ore and record the reading of the scintillator with the empty ring. This is the background reading. Compute the percent of U_3O_8 in the new sample by multiplying the percent of U_3O_8 in the assayed sample by the ratio of the reading of the new sample less background to the reading of the assayed sample less background. For example:

Report of chemically assayed sample	1.31%
Set 111B with assayed sample to read	1.31 MR/HR
If 111B with unknown new sample reads	.75 MR/HR
And 111B background reading as set is	.023 MR/HR

Percent U_3O_8 in unknown sample = (.75 -.023)/(1.31 -.023)*1.31 = .74% U_3O_8

With each method serious error may occur if the instructions are not precisely followed. It should be born in mind that methods "A" and "B" depend on the absence of thorium and equilibrium of the ore. While it is true that these factors may upset the results, it is also true that in some areas radiometric assays are considered sufficiently accurate to be used by ore buying stations.

When using any of the three methods the readings should always be taken at a location well removed from ore bodies.

XII. Special Factors Affecting Results

The air and all rocks and soils are radioactive to some extent. Their radioactivity is due to the presence of minute traces of relatively small numbers of radioactive elements including uranium. Because the radioactivity in rocks and soil is generally due to traces or "impurities," only general statements can be made concerning the amount of radioactivity associated with particular types of rock. In general, it may be said that granite, pegmatite and shale are likely to be more radioactive than limestone, quartzite, or sandstone. However, there will be many exceptions to this rule; for example, the highly radioactive carnotite is often found in sandstone.

Because of the effect of local topography (drainage ditches, rock outcrops, bogs, road cuts, etc.) on radioactivity distribution, care must be used in interpreting radioactivity readings if precise readings are desired.
In areas where shale may be at or near the surface, the radioactivity will usually be high. Lakes, swamps, and rivers usually produce low values of radioactivity. The radioactivity over a fresh road cut will frequently be abnormal (either high or low). Radioactivity readings frequently show a characteristic change over faults, being higher on one side than the other.

Radioactivity in the air commonly accounts for between 10 and 30 percent of the background reading observed in an unshielded scintillation counter located on the surface of the earth. The amount of radioactivity in the air at any given location may vary from day to day and with speed and direction of prevailing winds. There is some evidence that the radioactivity of the atmosphere is lower when barometric pressure is high. If precise readings of background radiation are being made, it is important to determine to what extent the atmospheric radioactivity is contributing to the measurement. The best measurements will thus be made on days of high barometric pressure and no wind. The effect of the atmosphere can be determined by repeating readings on successive days or at periods when the direction of prevailing winds has changed.

Scintillation counters do not respond to any ore that is not radioactive, but in taking readings for uranium, it should be remembered that thorium is also radioactive. There is no convenient way to distinguish between the readings obtained from uranium and thorium (other than chemical analysis). However, since thorium is also a valuable mineral this is not a serious disadvantage.

Prospectors are occasionally misled by the "mass effect" and believe they have found a valuable uranium deposit, when actually they are in the presence of a large body of very low grade ore which is valueless. In general, readings of several times background are not significant unless a small sample which gives a good reading can be found either at the surface or below the surface. If good readings can be obtained in an area, but not from an individual ore sample this indicates that either the ore body is deeply buried or that the reading is due to the "mass effect." Another situation in which "mass effect" becomes an important factor is when the probe is placed in a hole in the ground. If the soil is even slightly radioactive, the measurement taken is the *total* of the radiation coming from the soil all around the probe and will therefore produce a higher reading than when the probe is at the surface and is being influenced only by radioactivity coming from the surface.

Erroneous readings may result if the instrument is used at temperatures above 115° Fahrenheit. At temperatures above 115° Fahrenheit the so-called dark current from the photomultiplier tube may increase. This increase of current from the photomultiplier tube is registered by the meter on the instrument as an increase in radiation intensity. The photomultiplier tube is located in the probe. When using the instrument
above 115° Fahrenheit, the probe may be cooled by wrapping a piece of cloth around it, similar to the cloth used for Army canteen covers. This cloth should be dampened. The resultant evaporation of moisture from the cloth will cool the entire probe, including the photomultiplier tube.

Readings with the instrument will be affected by the presence of ice and snow on the ground. Ice is a efficient absorber of gamma radiation, gamma rays will be absorbed by the ice if it is three or four feet thick. The extent that snow will absorb the gamma radiation depends upon the layer of snow and how closely it is packed.

The amount of radioactivity present varies directly with altitude. When using the Scintillator in an aircraft, it is essential to make allowances for variations in altitude due to the local topography. For example, when passing over even a small hill an increase in reading should be expected since in effect the aircraft is closer to the ground when

passing over the hill. False indications may occur from the ignition system of the aircraft. If this happens, the condition can be corrected by using suppressors on the spark plugs and by grounding the probe of the Scintillator to the frame of the aircraft.

XIII. Oil Exploration with Scintillation Counters

The art of oil exploration with scintillation type instruments is at present in an experimental stage. A theory has been advanced to account for the pattern, or anomaly, of radiation existing over known oil fields. The validity of the theory is questioned by some individuals working in the field of oil exploration. They feel that not enough statistical results are as yet available in the form of reports on new producing oil wells whose existence was predicted by this method. However, there is a considerable body of opinion which holds that scintillation type instruments are a valuable aid in oil exploration.

The Model 111B has frequently been used for oil exploration. However, it cannot be recommended for this purpose. The very small measurements that must be made in this type of work require an instrument of much greater sensitivity such as the Model 118 ROYAL SCINTILLATOR.

XIV. Theory of Operation

The Model 111B "Scintillator" employs a 1 ½ x 1" sodium iodide crystal (Model 117 uses a ½″ x 1" crystal) with an RCA 6199 photomultiplier tube. The tube is enclosed in a magnetic shield to prevent defocusing by the earth's magnetic field. When gamma rays penetrate the crystal, they cause it to scintillate or throw off minute flashes of light. The light flashes are converted to electrical pulses by the photomultiplier tube and the tube greatly amplifies these pulses.

The voltage pulses produced by the photo tube vary widely in size. In the portion of the circuit following the phototube they are converted to pulses of identical shape and amplitude. The average rate of arrival of these uniformly shaped pulses is then measured in a continuously integrating voltmeter which thus indicates the average counting rate. A relaxation oscillator power supply is used to obtain the thousand volts required for the photomultiplier tube. When current which has been flowing through an inductance or choke coil is suddenly cut off a large transient voltage appears across the coil. In the power supply circuit a pentode vacuum rube is used to establish a steady current in a choke coil and a neon tube connected as an oscillator periodically (about 100 times a second) interrupts the choke current. The resulting surges of voltage across the coil are rectified and filtered to produce the steady high voltage needed to operate the photomultiplier. A corona discharge type voltage reference tube is used to return a portion of the output high voltage to the grid of the pentode, and thus the average current in the pentode and choke are controlled to produce a constant value of high voltage independent of battery voltages.

XV. Preventive Maintenance and Battery Replacement

An occasional calibration check assures the user that batteries and other electronic components are in proper working order. The first indication of weak batteries is an inability to recalibrate the instrument. Replacing the batteries is easily accomplished by simply pulling them out of the box. Care should be taken when making replacement to be sure that negative and positive terminals are properly connected. The batteries last much longer under intermittent use than when used continuously. Under intermittent conditions, a complete replacement of the batteries should only be necessary approximately once a year in the Model 111B and twice a year in the Model 117. In the event the instrument is stored for long periods such as one year, the batteries should be removed. Even at freezing temperatures, batteries can be stored successfully for several years. However, the life of a battery in use at 32˚F will be only a few percent of normal.

BATTERY COMPLEMENT:

MODEL 111B

2 RCA #VS016 or 2 Eveready #467 - 67 ½ volt

2 RCA #VS084 or 2 Eveready #412 - 22 ½ volt

4 RCA #VS036 or 4 Eveready # D99 - 1 ½ volt

MODEL 117

2 RCA #VS055 or 2 Eveready #455 - 45 volt

1 RCA #VS084 or 1 Eveready #412 - 22 ½ volt

4 RCA #XS036 or 4 Eveready #D99 - 1 ½ volt

The 1 ½ volt D99 batteries should be replaced only by new D99 batteries, or equivalent leakproof cells.

Although ruggedly constructed, the Scintillator is an electronic instrument and should be treated accordingly. It can be damaged by improper or rough treatment.

XVI. Corrective Maintenance

Access can be gained to the circuit components of the Model 111B by simply twisting and then pulling the two halves of the probe apart. To service the Model 117, simply open the two latch fasteners and lift the instrument out of its case.

In both units the crystal is hermetically sealed in an aluminum can with a plastic window and this assembly should never be opened as even minute amounts of moisture will damage the crystal. Failure can be due to the common faults of electronic circuits, such as burned out resistors, shorted condensers, tubes, etc. Standard servicing techniques may be used with certain exceptions. Because many ohmmeters produce enough voltage to burn out subminiature tube filaments, such tubes should never be checked directly for filament continuity. The filament can be safely checked by placing a thousand ohm resistor in series with the ohmmeter. The resistance of a normal filament will then be read as a very small increase over the value of the thousand ohm resistor. The 1000 volts across the photomultiplier tube can be measured accurately only with an electrostatic voltmeter. Any ordinary meter, even of the vacuum tube type, will load the circuit sufficiently to cause a drop in voltage of 100 volts or more. An oscilloscope with a fast preamplifier and triggered sweep not slower than five microseconds may be required for some servicing functions. Ordinary service shops do not have such equipment and an otherwise qualified service man, inexperienced with Scintillation Counters, could seriously damage the photomultiplier assembly. It is advisable, therefore, for servicing to be performed by a shop experienced with Scintillation Counters and properly equipped.

XVII. Laboratory Calibration Procedure

A gamma ray source of known value (in MR/HR) must be used to recalibrate the Scintillator. It is desirable to use a radium source for this purpose. A source which will produce an intensity of 1 MR/HR is necessary for most accurate calibration. A radium source of one millicurie equivalent radium strength will produce an intensity of 0.97 MR/HR at a distance of one meter. Intensities at other distances can be computed by using the inverse square law.

Place the source at a distance from the center of the crystal so that the calculated intensity at the center of the crystal will equal 3/4 full scale deflection on the range being used. Remove the cap nut from the "CALIBRATION ADJUST" control after checking the zero setting, adjust this control until the meter reads the calculated intensity *plus* background intensity and scattering. The instrument will then be properly calibrated.

XVIII. Guarantee and Factory Service

All parts except the batteries are guaranteed for a period of ninety days from date of purchase against defects in workmanship and material. The batteries cannot be guaranteed as they may be easily damaged by misuse. Always check the batteries before returning the instrument for factory service. To obtain service, pack the instrument carefully, and return it insured and prepaid to the factory. If you prefer to use a local repair shop write us and we will advise you of the name of the closest factory authorized service shop. The instrument should be covered on all sides with a thick layer of soft packing material. Enclose a note stating exactly in what way the instrument has not been performing properly, from whom it was purchased and the date of purchase.

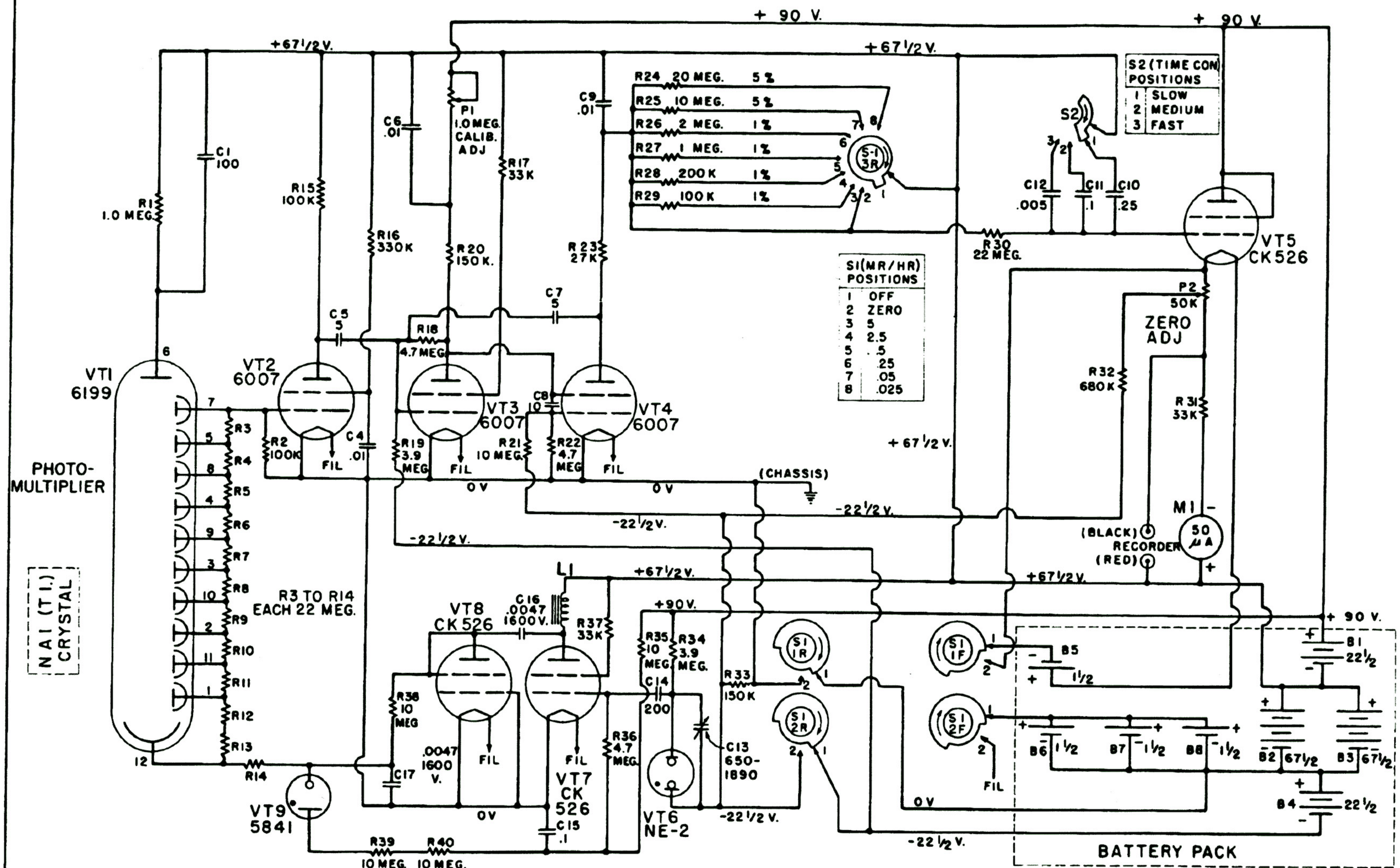
Ship it to:

PRECISION RADIATION INSTRUMENTS, INC.

2235 S. LA BREA AVENUE

LOS ANGELES 16, CALIFORNIA

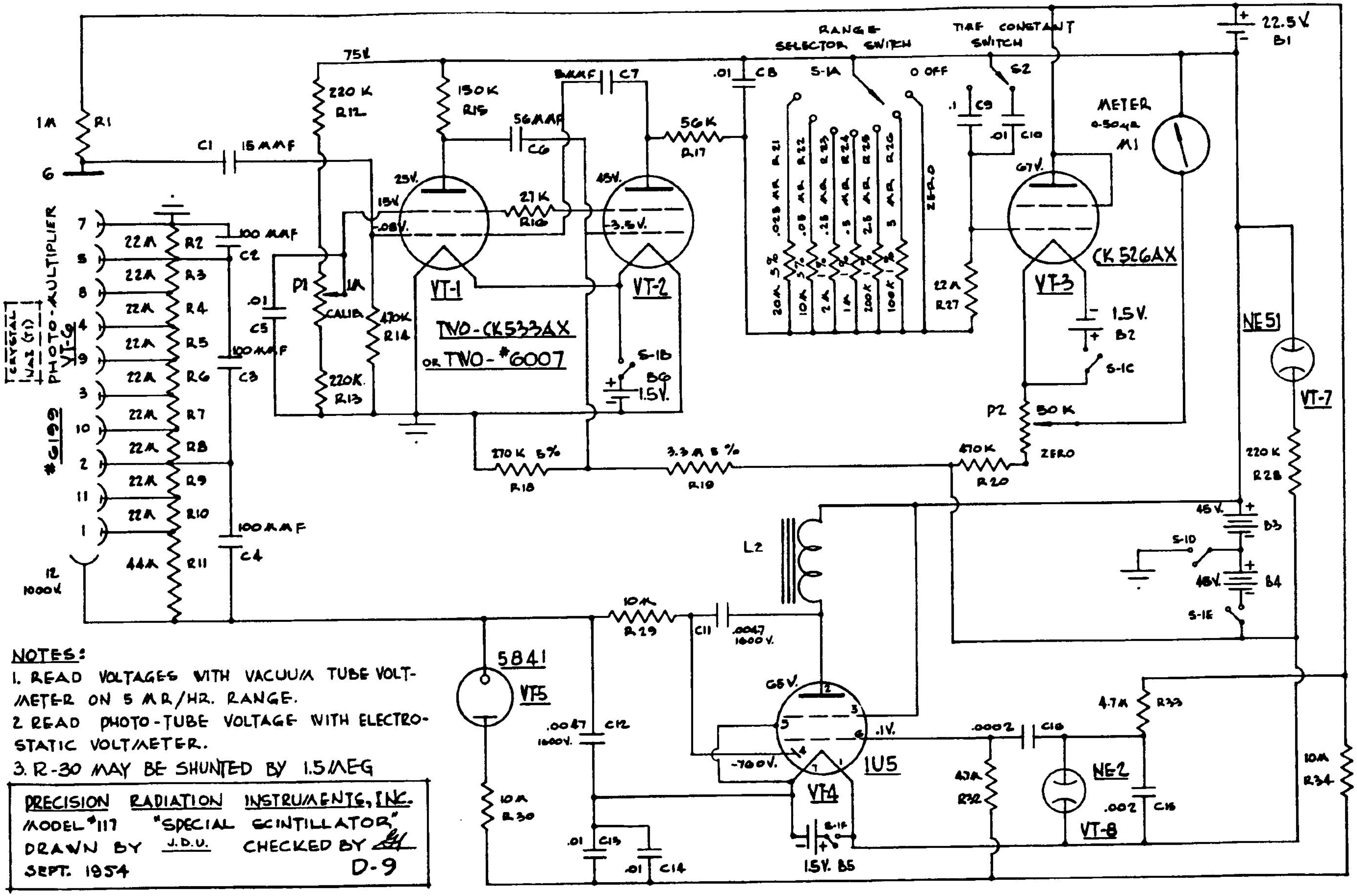
World's Largest Manufacture of Portable Radiation Insturments



NOTES:-

1. ALL SWITCHES SEEN FROM KNOB END, DECK "1F" IS FRONT (KNOB) SIDE OF DECK NEAREST KNOB, ETC.
2. ALL CAPACITORS GREATER THAN 1 ARE IN $\mu\mu$F ALL LESS THAN 1 IN μF.D.
3. VOLTAGES SHOWN TO CHASSIS WITH S1 IN "ZERO" POSITION.
4. ONE OR MORE RESISTORS (R14, R39 OR R40) MAY BE SHORTED OUT TO ADJUST HIGH VOLTAGE.

PRECISION RADIATION INSTRUMENTS, INC.
MODEL 111 B
-SCINTILLATOR-
DRAWN BY HRO.
CHECKED BY
DEC. 1954



NOTES:

1. READ VOLTAGES WITH VACUUM TUBE VOLTMETER ON 5 MR/HR. RANGE.
2. READ PHOTO-TUBE VOLTAGE WITH ELECTROSTATIC VOLTMETER.
3. R-30 MAY BE SHUNTED BY 1.5 MEG

PRECISION RADIATION INSTRUMENTS, INC.
MODEL #117 "SPECIAL SCINTILLATOR"
DRAWN BY J.D.U. CHECKED BY
SEPT. 1954 D-9